

CLAIMS

We claim:

1 1. A turbine vane, comprising:

2 a generally elongated hollow vane formed from an outer wall, the vane having
3 a leading edge, a trailing edge, a first end, a second end opposite the first end for
4 sealing the turbine vane to a rotatable disc, and at least one cavity forming a cooling
5 system in the vane;

6 at least one impingement insert in the at least one cavity forming an inner
7 cooling cavity and an outer cooling cavity, whereby the at least one impingement
8 insert includes at least one impingement orifice providing a gas pathway between the
9 inner cooling cavity and the outer cooling cavity;

10 at least one first pressure sensor for measuring pressure in the inner cooling
11 cavity; and

12 at least one second pressure sensor for measuring pressure between the
13 impingement insert and the outer wall of the turbine vane.

1 2. The turbine vane of claim 1, wherein the inner cooling cavity is divided

2 into an inner forward cooling cavity and an inner aft cooling cavity, and the at least
3 one first pressure sensor is positioned in one of the inner forward cooling cavity or
4 the inner aft cooling cavity, and wherein the outer cooling cavity is divided into an
5 outer forward cooling cavity and an outer aft cooling cavity, and the at least one
6 second pressure sensor is positioned in one of the outer forward cooling cavity or the
7 outer aft cooling cavity proximate to the inner cavity in which the at least one first
8 pressure sensor is positioned.

1 3. The turbine vane of claim 2, wherein each of the inner forward cooling

2 cavity and the inner aft cooling cavity includes a first pressure sensor, and each of
3 the outer forward cooling cavity and the outer aft cooling cavity includes a second
4 pressure sensor.

1 4. The turbine vane of claim 2, wherein the inner cooling cavity is further
2 divided into an inner mid cooling cavity between the inner forward cooling cavity and
3 the inner aft cooling cavity, and the at least one first pressure sensor is positioned in
4 one of the inner forward cooling cavity, the inner aft cooling cavity, or the inner mid
5 cooling cavity, and wherein the outer cooling cavity is further divided into an outer
6 mid cooling cavity between the outer forward cooling cavity and the outer aft cooling
7 cavity, and the at least one second pressure sensor is positioned in one of the outer
8 forward cooling cavity, the outer aft cooling cavity, or the outer mid cooling cavity
9 proximate to the inner cavity in which the at least one first pressure sensor is
10 positioned.

1 5. The turbine vane of claim 4, wherein at least two of the inner forward
2 cooling cavity, the inner aft cooling cavity, and the inner mid cooling cavity includes a
3 first pressure sensor, and at least two of the outer forward cooling cavity, the outer
4 aft cooling cavity, and the outer mid cooling cavity includes a second pressure
5 sensor.

1 6. The turbine vane of claim 4, wherein each of the inner forward cooling
2 cavity, the inner aft cooling cavity, and the inner mid cooling cavity includes a first
3 pressure sensor, and each of the outer forward cooling cavity, the outer aft cooling
4 cavity, and the outer mid cooling cavity includes a second pressure sensor.

1 7. An airfoil for use in a turbine engine, comprising:
2 a generally elongated hollow vane formed from an outer wall, the vane
3 forming at least one cooling cavity and having a leading edge, a trailing edge, and a
4 first end, a second end opposite the first end for sealing the vane to a rotatable disc,
5 and at least one cavity forming a cooling system in the vane;
6 at least one impingement insert in at least one cavity forming an inner cooling
7 cavity and an outer cooling cavity, whereby the at least one impingement insert
8 includes at least one impingement orifice providing a gas pathway between the inner
9 cooling cavity and the outer cooling cavity;

10 at least one first pressure sensor positioned in the inner cooling cavity for
11 measuring pressure in the inner cooling cavity; and
12 at least one second pressure sensor positioned in the outer cooling cavity for
13 measuring pressure between the impingement insert and the outer wall of the airfoil.

1 8. The airfoil of claim 7, wherein the inner cooling cavity is divided into an
2 inner forward cooling cavity and an inner aft cooling cavity, and the at least one first
3 pressure sensor is positioned in one of the inner forward cooling cavity or the inner
4 aft cooling cavity, and wherein the outer cooling cavity is divided into an outer
5 forward cooling cavity and an outer aft cooling cavity, and the at least one second
6 pressure sensor is positioned in one of the outer forward cooling cavity or the outer
7 aft cooling cavity proximate to the inner cavity in which the at least one first pressure
8 sensor is positioned.

1 9. The airfoil of claim 8, wherein each of the inner forward cooling cavity
2 and the inner aft cooling cavity includes a first pressure sensor, and each of the
3 outer forward cooling cavity and the outer aft cooling cavity includes a second
4 pressure sensor.

1 10. The airfoil of claim 8, wherein the inner cooling cavity is further divided
2 into an inner mid cooling cavity between the inner forward cooling cavity and the
3 inner aft cooling cavity, and the at least one first pressure sensor is positioned in one
4 of the inner forward cooling cavity, the inner aft cooling cavity, or the inner mid
5 cooling cavity, and wherein the outer cooling cavity is further divided into an outer
6 mid cooling cavity between the outer forward cooling cavity and the outer aft cooling
7 cavity, and the at least one second pressure sensor is positioned in one of the outer
8 forward cooling cavity, the outer aft cooling cavity, or the outer mid cooling cavity
9 proximate to the inner cavity in which the at least one first pressure sensor is
10 positioned.

1 11. The airfoil of claim 10, wherein at least two of the inner forward cooling
2 cavity, the inner aft cooling cavity, and the inner mid cooling cavity includes a first

3 pressure sensor, and at least two of the outer forward cooling cavity, the outer aft
4 cooling cavity, and the outer mid cooling cavity includes a second pressure sensor.

1 12. The airfoil of claim 10, wherein each of the inner forward cooling cavity,
2 the inner aft cooling cavity, and the inner mid cooling cavity includes a first pressure
3 sensor, and each of the outer forward cooling cavity, the outer aft cooling cavity, and
4 the outer mid cooling cavity includes a second pressure sensor.

1 13. A method of determining the presence of plugged impingement orifices
2 in an airfoil, comprising:

3 measuring a first pressure in an inner cooling cavity of an airfoil formed by an
4 impingement insert proximate to an outer wall of the airfoil to determine a first
5 pressure measurement;

6 measuring a second pressure in an outer cooling cavity between the
7 impingement insert and the outer wall of the airfoil to determine a second pressure
8 measurement;

9 determining a differential pressure between the inner cooling cavity and the
10 outer cooling cavity by comparing the first pressure measurement taken in the inner
11 cooling cavity with the second pressure measurement taken in the outer cooling
12 cavity; and

13 comparing the differential pressure with known benchmark differential
14 pressures to determine whether impingement orifices in the impingement insert are
15 plugged.

1 14. The method of claim 13, further comprising concluding that
2 impingement orifices are plugged when the differential pressure has changed by
3 more than about 1 pound per square inch.

1 15. The method of claim 13, wherein measuring a first pressure in an inner
2 cooling cavity of an airfoil comprises measuring an air pressure in an inner forward
3 cooling cavity and wherein measuring a second pressure in an outer cooling cavity
4 comprises measuring an air pressure in an outer forward cooling cavity.

1 16. The method of claim 15, further comprising concluding that orifices in
2 the impingement insert are plugged if the differential pressure increases or
3 concluding that the orifices in a suction side of the outer wall are plugged if the
4 differential pressure decreases.

1 17. The method of claim 13, wherein measuring a first pressure in an inner
2 cooling cavity of an airfoil comprises measuring an air pressure in an inner mid
3 cooling cavity and wherein measuring a second pressure in an outer cooling cavity
4 comprises measuring an air pressure in an outer mid cooling cavity.

1 18. The method of claim 17, further comprising concluding that orifices in
2 the impingement insert are plugged if the differential pressure increases or
3 concluding that the orifices in a pressure side of the outer wall are plugged if the
4 differential pressure decreases.

1 19. The method of claim 13, wherein measuring a first pressure in an inner
2 cooling cavity of an airfoil comprises measuring an air pressure in an inner aft
3 cooling cavity and wherein measuring a second pressure in an outer cooling cavity
4 comprises measuring an air pressure in an outer aft cooling cavity.

1 20. A method of determining burn off of a showerhead of an airfoil usable
2 in a turbine engine, comprising:

3 measuring a first pressure in an inner forward cooling cavity of an airfoil
4 proximate to a leading edge of the airfoil to determine a first pressure measurement;
5 measuring a second pressure in a combustor shell of the turbine engine to
6 determine a second pressure measurement;
7 determining a differential pressure between the inner cooling cavity and a
8 pressure outside the airfoil at the showerhead by comparing the first pressure
9 measurement taken in the inner cooling cavity with the second pressure
10 measurement taken in the outer cooling cavity; and

11 comparing the differential pressure with known benchmark differential
12 pressures to determine whether loss of the showerhead has occurred.